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Are Copper Vapour and Frequency Doubled Nd:YAG Lasers Superior to the Argon Laser for Portwine Stains at Pulse Widths of 30–50 Milliseconds?

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Background and objective: **The copper vapour laser (CVL) and the frequency doubled Nd:YAG laser (FDNYL) have been increasingly adopted as alternatives to the argon laser for treating vascular skin lesions. Automated scanning devices that permit the use of any of these lasers at 30–50 ms pulse widths are now widely used. The object of this study was to compare the CVL and FDNYL with the argon laser using pulse widths in the 30–50 ms range.**

Study Design/Materials and Methods: **Thirty-one adult patients with red-purple or purple portwine stains (PWS) were treated with a CVL at 578 nm, a FDNYL at 532 nm, and an argon laser at 488/514 nm. Test areas were performed using a Hexascan delivery system and an energy fluence just sufficient to produce immediate tissue change. Pulse widths were maintained constant for each patient (mean 40 msec). The mean fluences used were 13.1 J/cm^2, 13.2 J/cm^2, and 13.0 J/cm^2, respectively. Assessments were made after 4 months using a clinical fading score and an index of light absorbence derived from reflectance spectrophotometry.**

Results: **Fading scores were statistically significantly better with the CVL (score = 2.29) than the FDNYL (score = 1.83, $P < 0.02$) and the argon laser (score = 1.89, $P < 0.003$). The differences between the FDNYL and the argon laser were not significant. Although there was a trend toward lower light absorbence index with the CVL than the argon laser and FDNYL (scores = 177, 179 and 181, respectively), these differences were not statistically significant.**

Conclusions: **Despite slightly better results with the CVL in terms of the fading produced, differences among the CVL, FDNYL, and argon lasers are small when 30–50 ms pulse widths are employed and are of doubtful clinical significance for darker PWS.**

Key words: vascular malformation, skin, treatment

INTRODUCTION

The argon laser for many years was regarded as the treatment of choice for most cutaneous vascular lesions [1,2]. However, there are now a number of alternative lasers available for clinical use operating at wavelengths that are potentially superior. Among the lasers where pulse durations in excess of 30 ms are required for clinical effects, the copper vapour laser (CVL) emitting at 578 nm and the frequency doubled Nd:YAG laser (FDNYL) emitting at 532 nm have potential advan-

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tages over the argon laser, offering better light absorption by haemoglobin compared to melanin and better dermal penetration.

There have been few published studies comparing these lasers. We have previously shown superiority of the CVL over the argon laser for treating predominantly dark colored PWS when pulse widths in the region of 100–200 ms are employed [3]. Most histological and histochemical studies on laser treatment of vascular lesions have indicated that pulse widths in the region of 100–200 ms allow significant time for thermal diffusion away from target blood vessels, producing unwanted damage to nonvascular structures [4–6]. Theoretical studies suggest that this holds true with pulse widths longer than 1–10 ms [7].

Recent developments in laser delivery systems have permitted routine use of 30–50 ms pulses, depending on the delivery system used and the power output of the laser. The aim of this study was to investigate whether potential wavelength advantages of the CVL and the FDNYL over the argon laser are clinically significant at these shorter (but longer than theoretically ideal) pulse widths.

MATERIALS AND METHODS

Thirty-one patients with PWS were entered in the study (11 male and 20 female). Patients included those who had lesions that normally would be considered for treatment with the argon laser in our routine clinical practice. All patients had purple [22] or red-purple [9] lesions that failed to blanch fully on direct pressure and presented a large enough area with uniform appearance for placement of the treatment areas. The mean age was 39 years (range 20–70 years). Children were excluded, as is our usual practice when treating with the argon laser. The lesion was on the head and/or neck in 26 patients, on the trunk in 2 patients, on the arm in 2, and on the leg in one patient. Nine patients had received previous treatment with thorium-x. None of the patients had received previous laser treatment.

Treatments were performed without anaesthesia in an area of the PWS of uniform appearance and without evidence of clinical changes from previous treatments. Three test areas of ~1 cm in diameter were placed adjacent to each other. One area was treated with a Cu-15A CVL (Oxford Lasers, England), the output being filtered to emit only the 578 nm band. The second area was treated with an Innova 90 argon laser (Coherent, Palo Alto, CA) emitting at 488/514 nm. The third areas was treated with a FDNYL (Spectron Lasers, England) emitting at 532 nm. Treatments were administered using a Hexascan automated delivery system (Prein & Partners, Ferney-Voltaire, France) with a 1 mm spot at the 13 mm setting. The end of fibre power was determined by the internal power meter of the Hexascan. As is our routine practice, an energy fluence just sufficient to produce immediate visible tissue change (whitening or greying) was used. The mean energy fluence values for the CVL, argon, and FDNYL were similar (Table 1), and there was no statistically significant difference between them. The pulse width was determined by the maximum power output of the CVL and was held constant for the argon and frequency doubled Nd:YAG treatment areas within each patient. Thus pulse width varied from patient to patient. This was necessary because of the natural decay in maximum power output with time that occurred with the model of CVL used in this study. The mean pulse width was 40 msec (range 30–50 ms).

TABLE 1. Mean Skin Surface Energy Fluence With 95% Confidence Intervals for Copper Vapour Laser, Frequency Doubled Nd:YAG Laser, and Argon Laser

Energy fluence (J/cm^2)	Mean	95% confidence limits
Copper vapour laser	13.1 J/cm^2	12.0–14.2
Frequency doubled Nd:YAG laser	13.0 J/cm^2	12.0–14.1
Argon laser	13.2 J/cm^2	12.2–14.2

Patients were assessed at 4 months. Fading of the lesion was scored by a single observer on an open basis under uniform lighting conditions using a scale of 0–4 as indicated below:

0	poor	(little or no fading)
1	fair	(slight fading)
2	moderate	(moderate fading)
3	good	(marked fading)
4	excellent	(normal or near normal)

In addition, a skin reflectance spectrophotometer (Spectral Research) was used to provide an objective method of assessment of the test areas [8]. The reflectance spectrophotometer measures the intensity of back-scattered light at 150 wavelength intervals between 441 nm and 707 nm in the visible range of the spectrum. The logarithm of the inverse reflectance (LIR) is proportional to the light absorbence at each wavelength measured. We chose arbitrarily to use the area

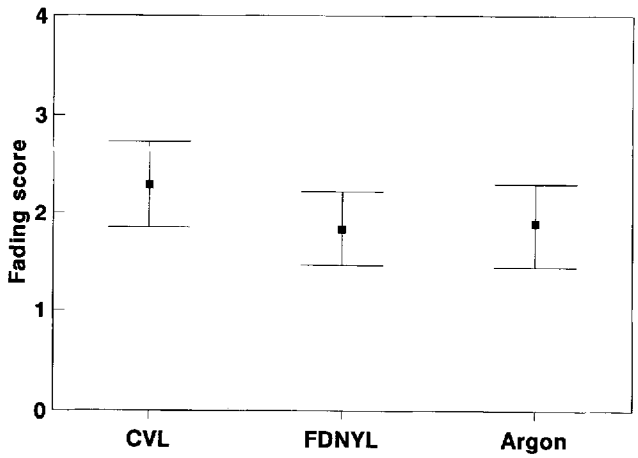

Fig. 1. Mean fading scores with 95% confidence intervals for copper vapour laser (CVL), frequency doubled Nd:YAG laser (FDNYL), and argon laser treated sites.

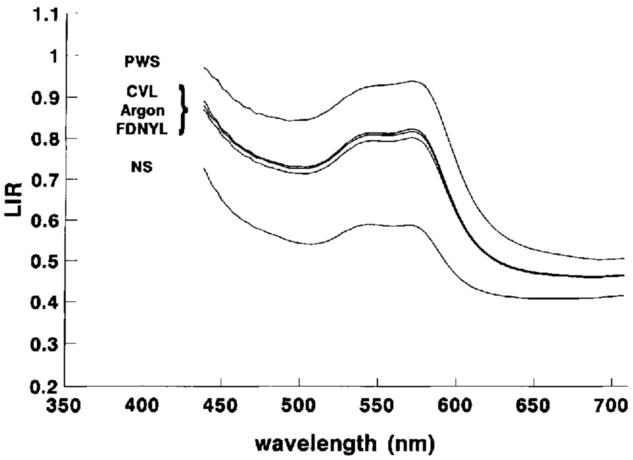

Fig. 2. Spectral reflectance curves for copper vapour laser (CVL), frequency doubled Nd:YAG laser (FDNYL), and argon laser treated sites. Untreated portwine stain (PWS) and normal adjacent skin (NS) values are shown for comparison.

under the absorbence curve derived from the 150 LIR values as an index of light absorbence in the visible range. Although this index does not relate directly to human visual experience, it does provide an objective assessment of light absorption by treated skin and allows some quantification of changes following laser treatment. Three readings were taken at each site and the average computed.

Any adverse events were noted, in particular the presence of hypopigmentation or hyperpigmentation, and any textural changes, which were scored on the following scale:

0 normal or near normal
1 light atrophy
2 moderate atrophy
3 marked atrophy
4 hypertrophic scar

Statistical analyses of treated areas were by Wilcoxen rank pairs test and student's *t*-test for nonparametric and parametric data, respectively.

RESULTS

The mean fading scores with 95% confidence intervals for the each of the test areas are shown in Figure 1. The CVL produced better fading scores compared with the argon laser ($P < 0.003$) and FDNYL ($P < 0.02$) as determined by a Wilcoxen rank pairs test. There was no statistically significant difference in fading score between the argon laser and the FDNYL.

The mean reflectance curves for each of the test areas together with those for untreated PWS and adjacent normal skin are shown in Figure 2. The mean absorbence index values with 95% confidence intervals for each of the test areas are shown in Figure 3 together with the values for untreated PWS and adjacent normal skin for comparison. Absorbence index values for the CVL, argon laser, and FDNYL treated areas were significantly lower than for untreated PWS and significantly higher than for normal adjacent skin ($P < 0.00005$) for all differences. The mean absorbence index value for the CVL was slightly lower than for the argon laser and FDNYL, but the differences were small and not statistically significant.

The frequency of adverse effects is indicated in Table 2. Atrophy occurred in three patients and appeared to be slightly more common with the argon laser. Marked atrophy was observed in one area treated with the CVL, following localised trauma in the immediate posttreatment period to that test area. However, the same patient exhibited slight atrophy in both the argon and FDNYL treated areas. None of the patients with atrophy had pigment disturbance. Hypopigmentation was observed in two patients, only with the argon laser. Hyperpigmentation occurred in three patients and was seen only with the CVL and FDNYL. Two patients exhibited hyperpigmentation in both CVL and FDNYL treated sites, one of whom also developed hypopigmentation in the argon treated site. The numbers exhibiting adverse

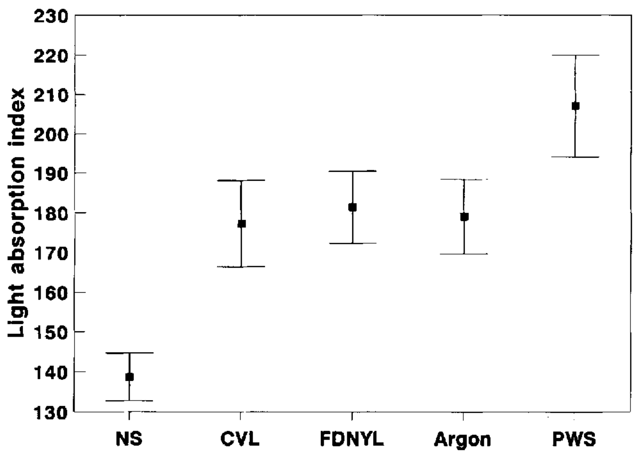

Fig. 3. Mean absorbence index values with 95% confidence intervals for copper vapour laser (CVL), frequency doubled Nd:YAG laser (FDNYL), and argon laser treated sites. Untreated portwine stain (PWS) and normal adjacent skin (NS) values are shown for comparison.

events were small and the differences between the three lasers were not statistically significant.

DISCUSSION

In this study we have demonstrated slightly better fading of PWS treated with the CVL compared with the argon laser and FDNYL by subjective clinical assessment when pulse widths of 30–50 ms are employed. Slightly better fading with the CVL was also observed as assessed objectively by reflectance spectrophotometry. However, the differences were marginal and of doubtful clinical significance. There were no significant differences in fading between the argon laser and the FDNYL as determined by clinical assessment and reflectance spectrophotometry.

Theoretically, the CVL emitting at 578 nm would be expected to have advantages over the FDNYL emitting at 532 nm for treating cutaneous vascular lesions by virtue of a more favourable absorption by haemoglobin relative to melanin (Fig. 4) [7,9]. A greater proportion of laser light would be absorbed by melanin in the epidermis at 532 nm, leaving less laser light available for absorption by haemoglobin. In addition, greater light absorption by melanin would be expected to produce greater thermal damage to the epidermis and adjacent dermal collagen. This might be expected to increase the risk of hypopigmentation and scarring. For similar reasons, the FDNYL would be expected to have advantages over the argon laser

TABLE 2. Adverse Events Observed for Copper Vapour Laser, Frequency Doubled Nd:YAG Laser, and Argon Laser

Adverse event	Texture score 1	Texture score 2	Texture score 3	Hypo-pigmentation	Hyper-pigmentation
Copper vapour laser	0	0	1	0	3
Frequency doubled Nd:YAG laser	1	0	0	0	2
Argon laser	3	0	0	2	0

emitting at 488 and 514 nm, for treating cutaneous vascular lesions (Fig. 4). In addition to the wavelength differences between the lasers used in this study, the CVL emits in a quasi-continuous wave mode consisting of high frequency (10 kHz) pulses of ~30 ns duration with a peak power of 75 kWatt. The FDNYL also emits in a quasi-continuous wave mode with Q-switched 15 ns pulses at 2.5 kHz. This differs from the "true" continuous wave output of the argon laser. The effect of the output mode on laser–PWS interaction and subsequent lesion fading is unclear, but our results suggest it is of little clinical significance when pulse widths of 30–50 ms are employed.

Studies based on mathematical modelling of laser treated PWS have suggested that the ideal pulse width lies in the range 1–10 ms [8]. It has been argued that pulse widths in this range allow thermal diffusion from haemoglobin that is just sufficient to produce blood vessel wall necrosis while minimising absorption by melanin in the epidermis. The 30–50 ms pulse widths employed in this study are longer than theoretically ideal. It seems probable that with pulse widths of 30–50 ms, there is significant thermal diffusion from target blood vessels and epidermal melanin. In these circumstances the extent of the nonvascular damage may be such that any advantages in terms of vascular selectivity due to differences in wavelength are considerably reduced.

There are little published comparative data on the CVL, argon laser, and FDNYL. In a previous study using a mean pulse width of 150 ms, we demonstrated better fading of PWS with the CVL (578 nm) compared with the argon laser (488/514 nm) using a technique of minimum energy fluence to produce visible tissue change [3]. However, in this study, the minimum energy fluence required to produce visible tissue change was greater for the CVL than the argon laser. It is interesting to note that in the present study, there was no significant difference in the mini-

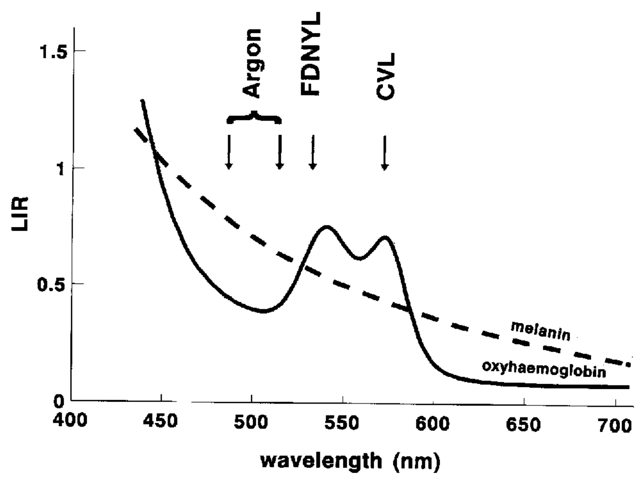

Fig. 4. Spectral reflectance curves for oxyhaemoglobin and melanin plotted as the logarithm of the inverse reflectance (LIR), with emission peaks for the copper vapour laser (CVL), frequency doubled Nd:YAG laser (FDNYL), and argon laser indicated as used in this study.

mum energy fluence required for tissue change between the three lasers. For longer pulse widths we postulated that thermal damage to the epidermis might be a major determinant of the tissue blanching process and that this would occur with lower fluences at the shorter argon wavelengths. Marini et al. [10] have suggested that with continuous wave lasers at shorter pulse widths, tissue blanching is due to vessel lumen occlusion. They have proposed that thermal damage to blood vessels causes disruption of the selective permeability of vascular endothelial cells, the damaged cells swelling to occlude the vessel lumen. It may be that with shorter pulse widths of 30–50 ms as used in the present study, tissue blanching is determined more by blood vessel occlusion than epidermal damage and that differences in wavelength between lasers are less important for this process.

On the basis of the results of this study, there would appear to be a marginal advantage in use of CVL for fading of PWS, but the differences over the argon laser and FDNYL are small and of doubtful clinical significance when pulse widths of 30–50 ms are employed. In these circumstances, the choice of laser for treating PWS might depend more on factors other than the degree of fading that can be achieved. Perhaps most important of these factors is the risk of adverse effects. We observed a marginal trend toward more frequent hypopigmentation and atrophy with the argon laser, which supports our own clinical observations (although the numbers in this study were too small for accurate assessment of this), and these problems may be more common after repeated treatments. It seems likely that the hypopigmentation with the argon laser results from excessive thermal damage to the epidermis as discussed above and that this is less marked with both the CVL and the FDNYL. In addition, there appeared to be a trend toward hyperpigmentation with the FDNYL and CVL. It is not entirely clear why these two lasers are associated with hyperpigmentation. However, we have observed minor degrees of purpura with both of these lasers in some patients, with onset several minutes after treatment. The high energy pulsed emission of these lasers could give rise to focal rupture of dermal vessels in a similar manner to what occurs with the flashlamp pumped pulsed dye laser, although the predominant effect seems to be of vessel occlusion with the CVL and the FDNYL. This purpura might result in hyperpigmentation either through haemosiderin deposition or stimulation of melanin production, or both.

Our study was not primarily designed to determine the incidence of adverse effects with these lasers, and further assessment in a more detailed study of multiple treatments would be required. If the incidence of adverse effects were similar for all three lasers, the choice of laser might be influenced more by other factors such as cost, reliability, availability, and individual patient preference.

It should be noted that in this study we used single test areas. Whereas test areas are generally good predictors of the subsequent response of the remainder of the lesion [11], in most circumstances multiple laser treatments are required for PWS, and the results of this study ideally should be confirmed by good comparative studies using multiple treatments on entire lesions.

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